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WATERTOWN ARSENAL LABORATORY

MEMORANDUM REPORT

NO. WAL 710/774

Investigation of Salvaged M1 Helmets

BY

A. Hurlich
Metallurgist

DATE 23 August 1945

WATERTOWN ARSENAL
WATERTOWN, MASS.

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WATERTOWN ARSENAL LABORATORY

MEMORANDUM REPORT No. WAL 710/774

Final Report on Problem B-7.13

23 August 1945

Investigation of Salvaged M1 Helmets

Abstract

Investigation of groups of helmets containing various types of defects for the purpose of determining whether or not salvage is possible indicate that:

a. No salvage should be attempted when helmets have been exposed to heat sufficiently intense to discolor the metal. Burning may cause carbide precipitation leading to severe embrittlement and consequent impairment of ballistic properties.

b. Dented helmets may be repaired without danger of increasing the susceptibility to service cracking when the dents are confined to the crown of the helmet. Salvaging of dented helmets is complicated by the difficulty of specifying the maximum severity of dent and location of dents considered repairable.

c. Pin holes in the chin strap loop welds neither impair the strength of the weldment nor lower the ballistic resistance to caliber .45 bullets. Pin holes probably lower the morale value of the M1 helmet and should, therefore, be corrected. The type of repair made on the subject helmets is considered adequate.

1. At the request of the Office, Chief of Ordnance[1], one hundred and seventy-five (175) helmets were forwarded to this arsenal from the Jeffersonville Quartermaster Depot, Jeffersonville, Indiana for metallurgical and ballistic investigation. The helmets comprised 7 lots each consisting of 25 helmets having a specific defect in either the defective or repaired condition as follows:

1. O.O. 400.93/27883, Wtn. 421/524 dated 27 June 1945.

25 helmets showing slight evidence of exposure to heat
25 helmets severely burnt
25 helmets having minor dents
25 helmets having the maximum dent considered economically reparacle
25 helmets from which the dents have been removed
25 helmets having pin holes at the chin strap loop
25 helmets which have been processed as combat serviceable with pinhole condition corrected.

2. This arsenal was requested to perform whatever tests considered advisable to determine if the preceding defects in either the defective or corrected condition impair the combat serviceability of the helmets.

3. Tests performed at this arsenal lead to the following observations and conclusions:

a. Burning, by its effect upon the microstructure of Hadfield manganese steel, may seriously reduce the ballistic resistance and ductility of helmets which have been exposed to heat. No attempt should be made to salvage burnt helmets for use in combat.

b. Dented helmets are believed repairable although it is recognized that the setting up of specifications to limit the maximum size and type of dent which can be repaired is very difficult.

c. A limited number of acid etching tests disclose that salvaged dented helmets are probably no more susceptible to service cracking than are undamaged helmets.

d. Pin holes in the chin strap loop welds do not impair either the strength of the weldment or its ballistic resistance to caliber .45 bullets. Pin holes would undoubtedly lower the morale value of the helmet and for this reason should be corrected. The type of repair applied to the subject helmets is considered satisfactory.

e. The economic aspects of salvaging damaged M1 helmets must be seriously considered. Salvage of M1 helmets may not be justified in view of the low cost of new helmets, particularly if the salvage cost approaches the initial cost of the item.

4. The tests conducted upon the helmets consisted of the following:

a. Visual examination.
b. Ballistic tests.
c. Metallographic examination of burnt helmets.
d. Bend test of burnt helmets.
e. Tensile tests of chin strap loop weldments.

5. The details of the tests follow:

a. Burnt Helmets. The distinction between helmets described as showing slight evidence of exposure to heat and those described as being severely burnt was apparently based upon the relative amount of surface area discolored by oxides formed upon heating and not upon the temperature to which the helmets were heated. It is impossible to estimate by visual examination the temperature to which the helmets were heated; the burnt zones in almost all cases being dull brown in color. Some regions within the burnt zones, presumed to have been heated to the highest temperatures, were colored black.

Five slightly burnt helmets numbered B1 to B5 and eight severely burnt helmets numbered SB1 to SB8 were selected for ballistic tests with gilding metal jacketed caliber .45 M1911 pistol ball ammunition. The bullets were fired at velocities close to the ballistic limit of the helmets, not primarily to determine if complete penetrations would occur, but to observe if the helmets would behave brittlely or in an otherwise unusual manner. The results of the ballistic tests are contained in Tables IA and B.

Four of the five slightly burnt helmets reacted normally to the ballistic tests. One slightly burnt helmet, No. B5, exhibited brittleness in the burnt zone by cracking upon being impacted at a velocity of 726 ft/sec. One crack occurred from the edge of the helmet through the point of impact and a second crack occurred one inch away from the point of impact.

Four of the severely burnt helmets exhibited normal ballistic properties while the remaining four displayed greater or lesser degrees of brittleness. Although no actual ballistic limits could be determined in the burnt zones it was obvious from the results obtained that the ballistic resistances of burnt areas can be considerably reduced from their original levels. Helmet SB7 suffered a complete penetration at 757 ft/sec. through having a 1"x1.5" piece blown out upon impact. The appearance of the penetration leads to the belief that complete penetration would also have occurred at a considerably lower velocity.

To demonstrate the brittleness of the burnt areas, the sides of some of the severely burnt helmets were gripped in the jaws of a vise and the protruding portions of the helmet shells were struck with a hammer. Extensive cracking, of which the photograph in Figure 1A is an example, occurred in several of the burnt helmets. In fact, the major amount of the cracking in helmet SB7, Figure 1A, occurred when the vise was tightened sufficiently to straighten out the curvature at the helmet rim. Similar treatment of unburnt helmets produced no cracking whatsoever even when the helmets were considerably deformed by the blows of the hammer.

Metallographic examination of the burnt areas of several of the helmets indicated that some of them had been heated to well over 600°F. Above approximately 600°F., austenitic manganese steel is unstable with respect to precipitation of carbides along slip planes and grain boundaries. Carbide precipitation results in severe embrittlement of the steel. Excellent data regarding the effect of reheating Hadfield Manganese steel are contained in a report entitled "Factors Involved in Stress-relief Annealing of Cold-worked Hadfield Manganese Steel," which was prepared for the Ordnance Department by the United States Steel Corporation Research Laboratory in October 1943.

Figure 1B shows the microstructure of the burnt zone of helmet SB7. Very extensive carbide precipitation is evident. The microstructure of the portion of the helmet which was unaffected by the heat consists of the normal cold-worked austenitic structure free of carbides.

In view of the possibility that any burnt helmet may have been heated to a sufficiently high temperature (above approximately 600°F.) to cause carbide precipitation and consequent embrittlement, it is deemed inadvisable to attempt the salvage of any burnt helmet. elmets should never be allowed to undergo combat service.

b. Dented Helmets. Visual examination of the dented helmets disclosed that practically all of the dents occur in the crown of the helmet. This would be expected since the crown is at the same time the thinnest and the [illegible] portion of the helmet. The extreme variation in the size, shape, location, and appearance of the dents emphasize the great difficulty of attempting to specify the maximum dent considered repairable.

Since the susceptibility to service cracking is the only factor which salvaging of dented helmets is believed capable of affecting, the only test conducted upon dented and repaired helmets was the acid etch test. Etching in dilute phosphoric acid until a weight loss of from 10 to 30% occurs has been found to be an excellent accelerated test to determine the susceptibility of helmets to age cracking.

Seven helmets containing minor dents and seven helmets from which the dents had been removed were weighed and etched for 16 hours in a 5% phosphoric acid solution. The helmets were weighed again after etching and examined for cracks. The results are listed in Table II. Two of the dented helmets and two of the salvaged helmets developed cracks upon etching. The cracks were located in the zones which have previously been determined as containing the highest residual stresses and being most susceptible to service cracking, namely, the visor and the vertical portion of the helmet body at the back of the helmet. The fact that the incidence of cracking is no greater in the salvaged helmets than in the dented helmets indicates that the salvaging process probably does not increase the susceptibility to service cracking. The fact that cracking upon acid etching did occur is not surprising because the lot numbers stamped upon the inside of the helmets indicated them to have been manufactured several years ago at which time service cracking was a serious problem

Analysis of factors involved in the salvaging of repairable dented helmets leads to the conclusion that the salvaging process should in no way affect the ballistic characteristics or the susceptibility to service cracking. The reduced hardness, and consequent increased ductility, of the crown renders the repair of dented helmets a relatively safe procedure.

c. Helmets with pinholes in chin strap loop welds. Pin holes in the chin strap loop spot welds are presumably due to a too high welding current or to a too long application of welding heat resulting in the burning through of the loop attachment and the helmet shell. It is conceivable that such pin holes may lower the ballistic resistance of the helmet in the region of the spot welds and may also lower the strength of the welded joints. Hence ballistic and tensile tests were conducted to determine if the pin hole condition required correction before the helmet could be considered battleworthy and also to determine if helmets in which the pin hole condition was rectified by depositing weld metal in the pin holes are satisfactory for battle use.

The ballistic tests consisted of firing caliber .45 M1911 pistol ball ammunition into the region of the chin strap loop spot welds of three groups of helmets consisting of the following:

a. Burnt helmets in which the chin strap loop welds were in the region unaffected by the heat

b. Helmets with pin holes in the chin strap loop welds

c. Helmets whose pin holes were repaired by welding.

The results of the ballistic tests are contained in Tables IA, B, C, and D. It is concluded that the presence of pin holes has little or no influence upon the resistance to caliber .45 bullets. The spot welds themselves seem to lower the resistance to ballistic impact somewhat regardless of whether or not pin holes occur in the welds.

Tensile tests of the spot welded loop attachment were conducted by fastening the helmet in a jig and pulling upon the loop attachment in a direction perpendicular to the wall of the helmet shell. The results of the tensile tests are contained in Table III. Comparison of the first and third columns of Table III demonstrate that pin holes do not weaken the attachment of the chin strap loop. The repair of pin holes by depositing weld metal in the pin holes causes a considerable increase in the strength of the weldment over that of normal and satisfactory welds.

In view of the fact that neither the ballistic resistance nor the strength of the welded joints seem to be impaired by the presence of pin holes, the question as to the need of repairing this type of defect naturally arises. From the morale viewpoint it may well be undesirable to tolerate pin holes in the weld joint, but the entire problem of salvaging helmets with pin holes in the chin strap loop welds should be reviewed.

6. A very important factor which must be considered is the relation between the cost of salvaging repairable helmets and the initial cost of the M1 helmet. Although no information regarding the cost of salvage is available at this arsenal, it is conceivable that the salvage cost may be sufficiently high to render the salvaging of M1 helmets uneconomical.

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APPROVED:

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TABLE I

Ballistic Tests of Salvaged Helmets

Cal. .45 M1911 Pistol Ball - Gilding Metal Jacketed Soft Lead Bullets

A. Slightly Burnt Helmets

Helmet No.	Round No.	Velocity Ft./Sec.	Location of Impact	Result
B1	1	772	0.5" up from edge of visor, in burnt zone.	GP, 1.1"x1.1" petal folded back.
	2	801	0.6" up from edge, no burning, impact on loop spot welds.	GP, 1.0"x0.5" petal folded back.
B2	1	770	0.3" up from edge, in burnt zone.	GP, 1.1"x1.0" petal folded back.
	2	757	0.6" up from edge, no burning, impact on loop spot welds.	PP, no cracking.
B3	1	769	0.5" up from edge, in burnt zone.	PP, no cracking.
B4	1	735	6.0" up from edge, in burnt zone.	PP, diameter of indent - 4".
	2	788	0.5" up from edge, no burning, impact on loop spot welds.	GP, 1.0"x0.9" petal folded back.
B5	1	726	0.7" up from edge of visor, in burnt zone.	PP, 0.7" crack to edge of helmet. 1.3" vertical crack from edge of helmet 1.0" to right of impact

TABLE I (Cont'd)

B. Severely Burnt Helmets

Helmet No.	Round No.	Velocity Ft./Sec.	Location of Impact	Result
SB1	1	769	1.1" up from edge of visor in burnt zone.	CP, 1.2"x1.1" petal folded back. 1.2" long vertical crack 0.8" from point of impact.
	2	773	0.5" up from edge, no burning, impact on loop spot welds.	CP, 1.5"x0.8" petal folded back.
SB2	1	789	3.0" up from edge in burnt zone.	PP, diameter of indent - 3". 1.8" long vertical crack extending from edge of helmet to within 1" of impact.
	2	741	0.5" up from edge, no burning, impact on loop spot welds.	PP, no cracks.
SB3	1	773	0.5" up from edge in burnt zone.	PP, no cracks.
SB4	1	769	1.5" up from edge in burnt zone.	CP, 0.9"x1.5" petal folded back.
	2	796	0.5" up from edge, no burning, impact on loop spot welds.	CP, 1.0"x1.0" petal folded back.
SB5	1	809	1.5" up from edge, in burnt zone.	PP, diameter of indent - 2.5".
SB6	1	801	1.4" up from edge in burnt zone.	PP, diameter of indent - 3".
SB7	1	757	2.0" up from edge in burnt zone.	CP, 1.0"x1.5" piece blown out.
SB8	1	741	2.5" up from edge in burnt zone.	CP, 1.5"x2.3" petal folded back, 1.5" vertical crack in burnt zone in other side of helmet caused by bullet passing through helmet.
	2	795	2.0" up from edge in burnt zone.	PP, diameter of indent - 3.5".

TABLE I (Cont'd)

G. Helmets with Pin Holes at Chin Strap Loops

Helmet No.	Round No.	Velocity Ft./Sec.	Location of Impact	Result
P1	1	765	On loop welds, 0.4" up from edge.	CP, 0.4"x0.8" piece blown out.
P2	11	731	On loop welds, 0.5" up from edge.	CP, 1.0"x0.5" opening.
P3	1	716	On loop welds, 0.2" up from edge.	PP, no cracks.
P4	1	738	On loop welds, 0.2" up from edge.	CP, 1.0"x0.2" petal folded back.
P5	1	781	On loop welds, 0.6" up from edge.	CP, 0.8"x0.6" piece blown out.
P6	1	675	On loop welds, 0.5" up from edge.	CP, 0.3"x0.8" petal folded back.
	2	784	2" to left of loop welds, 0.5" up from edge.	PP, 1.7" long vertical crack 1.2" away from penetration.

TABLE I (CONT'D)

D. Helmets with Chin Strap Loop Pin Holes Welded Shut

Helmet No.	Round No.	Velocity Ft./Sec.	Location of Impact	Result
W1	1	769	On loop welds, 0.3" up from edge.	CP, 0.5"x0.5" piece blown out.
	2	765	2" to left of loop welds, 0.4" up from edge.	CP, 1.2"x0.5" piece blown out.
W2	1	750	On loop welds, 0.2" up from edge.	PP, no cracks.
W3	1	750	On loop welds, 0.5" up from edge.	CP, 0.7"x0.6" piece blown out.
W4	1	773	On loop welds, 0.3" up from edge.	CP, 0.7"x0.4" petal folded back.
	2	781	2" to left of loop welds, 0.4" up from edge.	CP, 0.5"x0.5" piece blown out.
W5	1	793	On loop welds, 0.3" up from edge.	CP, 1.1"x0.7" petal folded back.
	2	774	2" to left of loop welds, 0.3" up from edge.	PP, no cracks.
W6	1	705	On loop welds, 0.4" up from edge.	CP, 0.5"x0.1" piece blown out.
	2	723	3" to left of loop welds, 0.2" up from edge.	PP, no cracks.

TABLE II

Acid Etching Tests of Dented and Repaired Helmets

(Etched in 5% Phosphoric Acid for 16 Hours)

I. Dented Helmets (Minor Dents)

Helmet No.	Weight before Etching - Grams	Weight after Etching - Grams	Weight Loss %	Cracks Developed
1	963	618	35.8	none
2	1027	904	12.0	Body cracks at 155°, 196°
3	986	786	20.3	none
4	987	828	16.1	Small edge crack at 18°
5	972	853	12.2	none
6	975	685	29.8	none
7	926	613	33.8	none

II. Helmets from Which Dents Were Removed

Helmet No.	Weight before Etching - Grams	Weight after Etching - Grams	Weight Loss %	Cracks Developed
1	965	567	41.2	none
2	1027	598	41.8	none
3	961	656	31.7	Body cracks at 175°, 218°
4	880	680	22.7	Small edge crack at 333°
5	1010	841	16.7	none
6	988	831	15.9	none
7	971	750	22.8	none

TABLE III

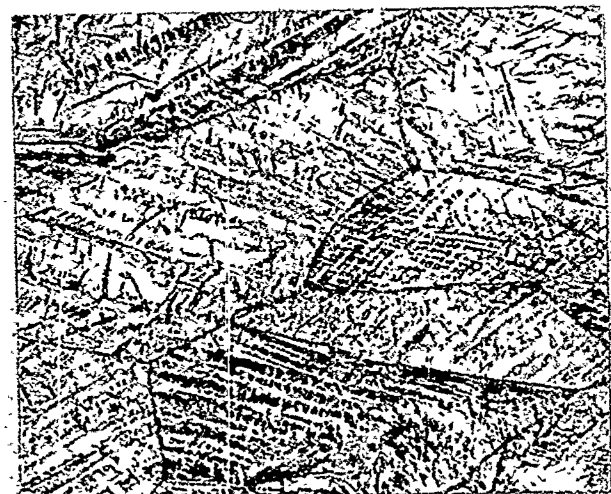
Static Tensile Tests of Chin Strap Loops

(Loops Pulled Away from Helmet Shells in Horizontal Direction)

Helmets with Pin Holes in Chin Strap Loops Breaking Strength of Loop Welds - Pounds	Helmets with Pin Holes in Chin Strap Loops Repaired by Welding Breaking Strength of Loop Welds - Pounds	Helmets with No Pin Holes in Chin Strap Loops Breaking Strength of Loop Welds - Pounds
135	350	250
350	335	245
360	260	220
245	430	340
240	450	500
280	400	190
385	310	225
Average - 286 ± 70 pounds	Average - 362 ± 55 pounds	Average - 281 ± 80 pounds

Burnt Helmets

Severely burnt helmet. -A- Mag. X½
Impact of Cal. .50 ball broke out 1.0"x1.5" piece. Cracks resulted from gripping helmet in jaws of vise. Burnt zone is extremely brittle.



Nital Etch. -B- Mag. X1000
Microstructure of burnt zone of above helmet. Carbides precipitated at grain boundaries and along slip lines.

FIGURE 1.